Chapter 3 – ABOUT VARIABLE STARS

The Naming of Variable Stars

The name of a variable star generally consists of one or two capital letters or a Greek letter, followed by a three letter constellation abbreviation. There are also variables with names such as V746 Oph and V1668 Cyg. These are stars in constellations for which all of the letter combinations have been exhausted. (i.e. V746 Oph is the 746th variable to be discovered in Ophiuchus.) See the panel at right for a more detailed explanation of variable star names.

examples: SS Cyg
Z Cam
alpha Ori
V2134 Sgr

Table 3.1 (page 19) lists all of the official constellation name abbreviations.

There are also some special kinds of star names. For instance, sometimes stars are given temporary names until such time as the editors of the *General Catalogue of Variable Stars* assign the star a permanent name. An example of this would be N Cyg 1998—a nova in the constellation of Cygnus which was discovered in 1998. Another case is of a star that is suspected but not confirmed to be variable. These stars are given names such as NSV 251 or CSV 3335. The first part of this name indicates the catalogue in which the star is published, while the second part is the catalogue entry number for that star.

Variable Star Designations

In addition to its proper name, a variable star is also referred to by its *Harvard Designation*. This designation is simply an indication of a star's position coordinates, given in hours and minutes of right ascension (R.A.) plus or minus the degrees of declination (Dec.) of the star for epoch 1900. See sidebar on the next page for more information on how the Harvard Designation is determined.

examples:	2138+43	1405-12A
	0214-03	1151+58

Note that in one example given, the designation is followed by the letter "A". This is because there is another variable in the proximity, with the designation 1405-12B which was discovered later.

Variable Star Naming Conventions

Variable star names are determined by a committee appointed by the International Astronomical Union (I.A.U.). The assignments are made in the order in which the variable stars were discovered in a constellation. If one of the stars that has a Greek letter name is found to be variable, the star will still be referred to by that name. Otherwise, the first variable in a constellation would be given the letter R, the next S, and so on to the letter Z. The next star is named RR, then RS, and so on to RZ; SS to SZ, and so on to ZZ. Then, the naming starts over at the beginning of the alphabet: AA, AB, and continuing on to QZ. This system (the letter J is omitted) can accommodate 334 names. There are so many variables in some constellations in the Milky Way, however, that additional nomenclature is necessary. After QZ, variables are named V335, V336, and so on. The letters representing stars are then combined with the genitive Latin form of the constellation name as given in Table 3.1. For all but the most formal usage, and for reports you submit to the AAVSO, the three letter abbreviations should be used.

This system of nomenclature was initiated in the mid-1800s by Friedrich Argelander. He started with an uppercase R for two reasons: the lowercase letters and the first part of the alphabet had already been allocated for other objects, leaving capitals towards the end of the alphabet mostly unused. Argelander also believed that stellar variability was a rare phenomenon and that no more than 9 variables would be discovered in any constellation (which is certainly not the case!).

The Harvard Designation of Variable Stars by Margaret W. Mayall
from the *Journal of the AAVSO*, Volume 5, Number 1

In the late 1800's and early 1900's, Harvard College Observatory was the center of most variable star work. Director Edward C. Pickering encouraged both photographic and visual observations. Several catalogues of variable stars were published by the Observatory, and the number of known variables grew so large that astronomers felt the need for a designation that would give a better clue to location in the sky, rather than just a list by constellations. The result was the Harvard Designation, described in the Harvard Observatory *Annals*, vol. 48, p. 93, 1903.

Many suggestions were considered, and it was finally decided to use six numbers to indicate Right Ascension and Declination, epoch 1900. This method is not intended to give an accurate position. It is, as Webster's Dictionary says, an "indication." There has been some confusion concerning the method of determining the designation.

Suppose the position of a variable is given by Right Ascension in hours, minutes, and seconds of time and by Declination in degrees, minutes and tenths of arc, epoch 1900. The first step in determining the Harvard designation is to reduce the Right Ascension to hours, minutes, and tenths, and the Declination to degrees and whole minutes of arc. Then drop the tenths of Right Ascension and the minutes of Declination. The remaining six figures make up the Harvard Designation.

For southern variables, a minus sign is inserted before the degrees of Declination, or the degrees may be underscored or italicized.

Ambiguous cases are covered by a special rule. If, for example, the Right Ascension ends with 21 seconds, dividing by 60, to get tenths of minutes will give 0.35. In such cases, adopt the nearest even number, 0.4 in this case. As further examples, 51 seconds would give 8 tenths, and 57 seconds would give 0 tenths of the next higher minute. In the reduction of Declination, the critical case comes at 59 minutes. If the tenths are 5 or more, change the last two figures of the Designation to the next higher degree.

EXAMPLES

	Coordinates (1900)		Reduced		Designation
RR And	$00^h45^m57^s$	+ 33°50'.0	$00^h46^m.0$	+ 33°50'	004633
SU And	23 59 28	+ 42 59.7	23 59.5	+ 43 00	235943
TW Aqr	20 58 55	- 02 26.5	20 58.9	- 02 26	2058-02 or 205802
U Aur	05 35 38	+ 31 59.4	05 35.6	+ 31 59	053531

An easy way to remember the rule is that if the Right Ascension is 57 seconds or more, the minutes would be increased by one; if less, the minutes would not change. In Declination, if the minutes are 59'.5 or more, the Declination would increase 1°, if less, the Declination remains the same.

Table 3.1 – *Constellation Names and Abbreviations*

The list below shows the I.A.U. conventions for constellation names. Given for each constellation is the Latin name, nominative and genitive, as well as the approved three-letter abbreviation.

Nominative	***Genitive***	***Abbreviation***	***Nominative***	***Genitive***	***Abbreviation***
Andromeda	Andromedae	And	Lacerta	Lacertae	Lac
Antlia	Antliae	Ant	Leo	Leonis	Leo
Apus	Apodis	Aps	Leo Minor	Leonis Minoris	LMi
Aquarius	Aquarii	Aqr	Lepus	Leporis	Lep
Aquila	Aquilae	Aql	Libra	Librae	Lib
Ara	Arae	Ara	Lupus	Lupi	Lup
Aries	Arietis	Ari	Lynx	Lyncis	Lyn
Auriga	Aurigae	Aur	Lyra	Lyrae	Lyr
Bootes	Bootis	Boo	Mensa	Mensae	Men
Caelum	Caeli	Cae	Microscopium	Microscopii	Mic
Camelopardalis	Camelopardalis	Cam	Monoceros	Monocerotis	Mon
Cancer	Cancri	Cnc	Musca	Muscae	Mus
Canes Venatici	Canum Venaticorum	CVn	Norma	Normae	Nor
Canis Major	Canis Majoris	CMa	Octans	Octantis	Oct
Canis Minor	Canis Minoris	CMi	Ophiuchus	Ophiuchi	Oph
Capricornus	Capricorni	Cap	Orion	Orionis	Ori
Carina	Carinae	Car	Pavo	Pavonis	Pav
Cassiopeia	Cassiopeiae	Cas	Pegasus	Pegasi	Peg
Centaurus	Centauri	Cen	Perseus	Persei	Per
Cepheus	Cephei	Cep	Phoenix	Phoenicis	Phe
Cetus	Ceti	Cet	Pictor	Pictoris	Pic
Chamaeleon	Chamaeleontis	Cha	Pisces	Piscium	Psc
Circinus	Circini	Cir	Piscis Austrinus	Piscis Austrini	PsA
Columba	Columbae	Col	Puppis	Puppis	Pup
Coma Berenices	Comae Berenices	Com	Pyxis	Pyxidis	Pyx
Corona Austrina	Coronae Austrinae	CrA	Reticulum	Reticuli	Ret
Corona Borealis	Coronae Borealis	CrB	Sagitta	Sagittae	Sge
Corvus	Corvi	Crv	Sagittarius	Sagittarii	Sgr
Crater	Crateris	Crt	Scorpius	Scorpii	Sco
Crux	Crucis	Cru	Sculptor	Sculptoris	Scl
Cygnus	Cygni	Cyg	Scutum	Scuti	Sct
Delphinus	Delphini	Del	Serpens	Serpentis	Ser
Dorado	Doradus	Dor	Sextans	Sextantis	Sex
Draco	Draconis	Dra	Taurus	Tauri	Tau
Equuleus	Equulei	Equ	Telescopium	Telescopii	Tel
Eridanus	Eridani	Eri	Triangulum	Trianguli	Tri
Fornax	Fornacis	For	Triangulum Australe	Trianguli Australis	TrA
Gemini	Geminorum	Gem	Tucana	Tucanae	Tuc
Grus	Gruis	Gru	Ursa Major	Ursae Majoris	UMa
Hercules	Herculis	Her	Ursa Minor	Ursae Minoris	UMi
Horologium	Horologii	Hor	Vela	Velorum	Vel
Hydra	Hydrae	Hya	Virgo	Virginis	Vir
Hydrus	Hydri	Hyi	Volans	Volantis	Vol
Indus	Indi	Ind	Vulpecula	Vulpeculae	Vul

Types of Variable Stars

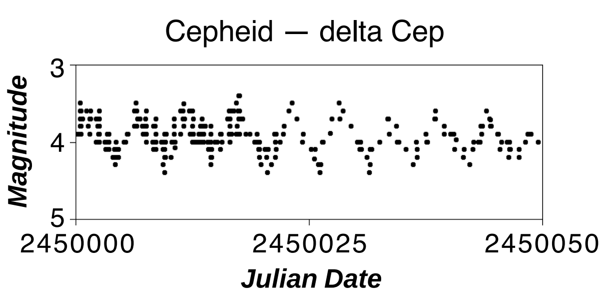
There are two kinds of variable stars: **intrinsic,** in which variation is due to physical changes in the star or stellar system, and **extrinsic,** in which variability is due to the eclipse of one star by another or the effect of stellar rotation. Variable stars are frequently divided into four main classes: the *intrinsic* **pulsating** and **cataclysmic** (eruptive) variables, and the *extrinsic* **eclipsing binary** and **rotating stars**.

Generally, long period and semiregular pulsating variables are recommended for beginners to observe. These stars have a wide range of variation. Also, they are sufficiently numerous that many of them are found close to bright stars, which is very helpful when it comes to locating them.

A brief description of the major types in each class is covered in this chapter. There is also mention of the star's spectral type. If you are interested in learning more about stellar spectra and stellar evolution, you can find information on these subjects in basic astronomy texts or in some of the books mentioned in Appendix 3.

PULSATING VARIABLES

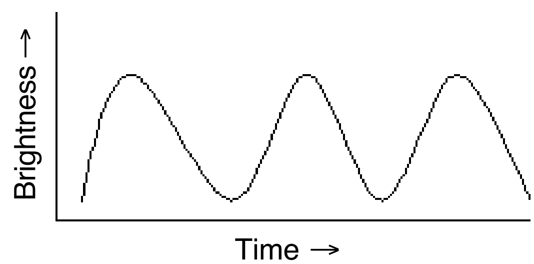
Pulsating variables are stars that show periodic expansion and contraction of their surface layers. Pulsations may be radial or non-radial. A radially pulsating star remains spherical in shape, while a star experiencing non-radial pulsations may deviate from a sphere periodically. The following types of pulsating variables may be distinguished by the pulsation period, the mass and evolutionary status of the star, and the characteristics of their pulsations.



<u>Cepheids</u> – Cepheid variables pulsate with periods from 1 to 70 days, with light variations from 0.1 to 2 magnitudes. These massive stars have high luminosity and are of F spectral class at maximum, and G to K at minimum. The later the spectral class of a Cepheid, the longer is its period. Cepheids obey the period-luminosity relationship. Cepheid variables may be good candidates for student projects because they are bright and have short periods.

What is a Light Curve?

Observations of variable stars are commonly plotted on a graph called a **light curve**, as the apparent brightness (magnitude) versus time, usually in Julian Date (JD). The magnitude scale is plotted so that brightness increases as you go from bottom to top on the Y-axis and the JD increases as you go from left to right on the X-axis.



Information about the periodic behavior of stars, the orbital period of eclipsing binaries, or the degree of regularity (or irregularity) of stellar eruptions, can be directly determined from the light curve. More detailed analysis of the light curve allows astronomers to calculate such information as the masses or sizes of stars. Several years or decades of observational data can reveal the changing period of a star, which could be a signal of a change in the structure of the star.

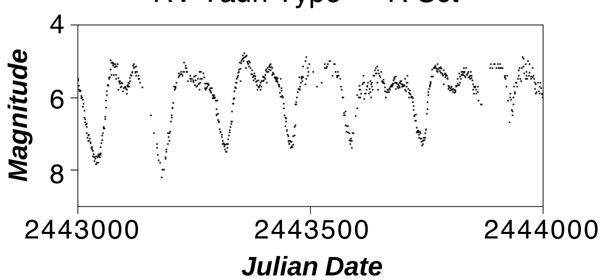
Phase Diagrams

Phase diagrams (also known as "folded light curves") are a useful tool for studying the behavior of periodic stars such as Cepheid variables and eclipsing binaries. In a phase diagram, multiple cycles of brightness variation are superimposed on each other. Instead of plotting magnitude versus JD as with a regular light curve, each observation is plotted as a function of "how far into the cycle" it is. For most variable stars, a cycle starts at maximum brightness (phase=0), runs through minimum and back to maximum again (phase=1). With eclipsing binary stars, phase zero occurs at mid-eclipse (minimum). An example of a phase diagram is given on page 23 of this manual to show the characteristic light curve of beta Persei.

RR Lyrae stars – These are short-period (.05 to 1.2 days), pulsating, white giant stars, usually of spectral class A. They are older and less massive than Cepheids. The amplitude of variation of RR Lyrae stars is generally from 0.3 to 2 magnitudes.

RV Tauri stars – These are yellow supergiants having a characteristic light variation with alternating deep and shallow minima. Their periods, defined as the interval between two deep minima, range from 30 to 150 days. The light variation may be as much as 3 magnitudes. Some of these stars show long-term cyclic variations from hundreds to thousands of days. Generally, the spectral class ranges from G to K.

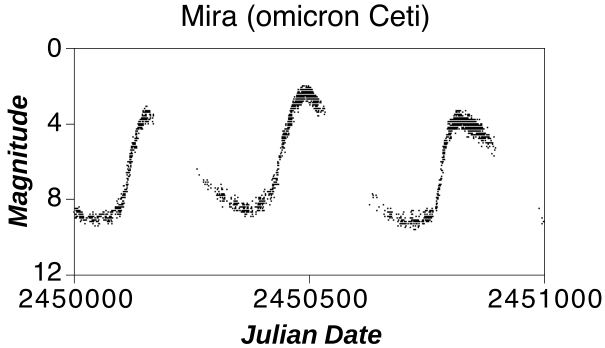
RV Tauri Type — R Sct



Long Period Variables – Long Period Variables (LPVs) are pulsating red giants or supergiants with periods ranging from 30-1000 days. They are usually of spectral type M, R, C or N. There are two subclasses; Mira and Semiregular.

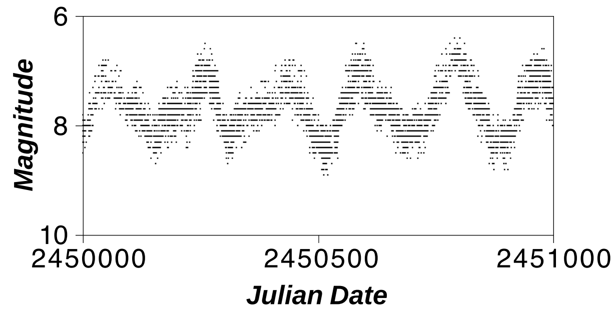
Mira – These periodic red giant variables vary with periods ranging from 80 to 1000 days and visual light variations of more than 2.5 magnitudes.

Mira (omicron Ceti)



Semiregular – These are giants and supergiants showing appreciable periodicity accompanied by intervals of semiregular or irregular light variation. Their periods range from 30 to 1000 days, generally with amplitude variations of less than 2.5 magnitudes.

Semiregular — Z UMa



Irregular variables

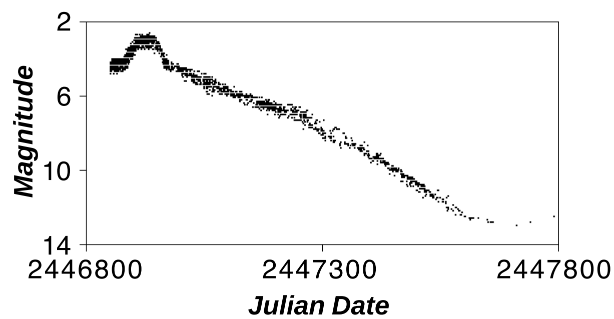
These stars, which include the majority of red giants, are pulsating variables. As the name implies, these stars show luminosity changes with either no periodicity or with a very slight periodicity.

CATACLYSMIC VARIABLES

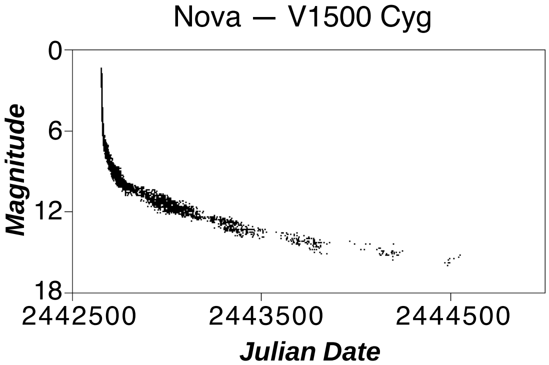
Cataclysmic variables (also known as Eruptive variables), as the name implies, are stars which have occasional violent outbursts caused by thermonuclear processes either in their surface layers or deep within their interiors.

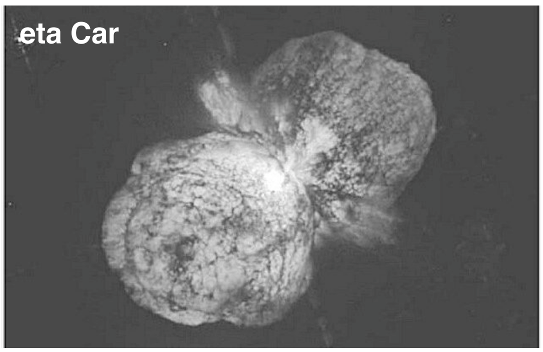
Supernovae – These massive stars show sudden, dramatic, and final magnitude increases of 20 magnitudes or more, as a result of a catastrophic stellar explosion.

SN 1987A



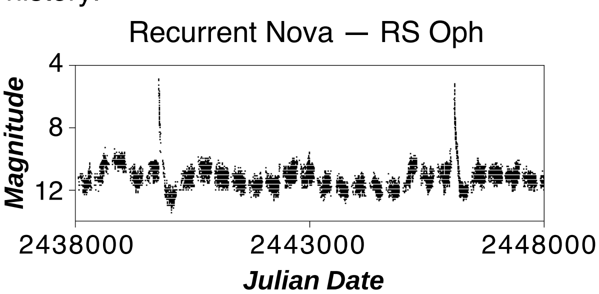
Novae – These close binary systems consist of an accreting white dwarf as a primary and a low-mass main sequence star (a little cooler than the Sun) as the secondary star. Explosive nuclear burning of the surface of the white dwarf, from accumulated material from the secondary, causes the system to brighten 7 to 16 magnitudes in a matter of 1 to several hundred days. After the outburst, the star fades slowly to the initial brightness over several years or decades. Near maximum brightness, the spectrum is generally similar to that of A or F giant stars.





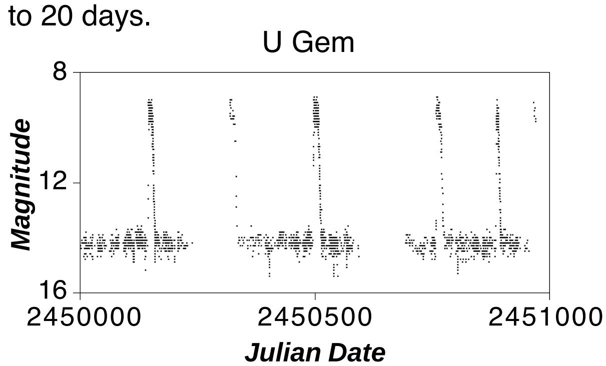
A huge, billowing pair of gas and dust clouds are captured in this stunning NASA Hubble Space Telescope image of the supermassive star eta Carinae. This star was the site of a giant outburst about 150 years ago, when it became one of the brightest stars in the southern sky. Though the star released as much visible light as a supernova explosion, it survived the outburst.

Recurrent Novae – These objects are similar to novae, but have two or more slightly smaller-amplitude outbursts during their recorded history.

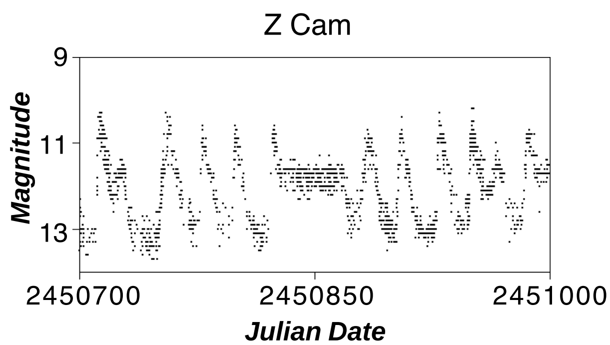


Dwarf Novae These are close binary systems made up of a red dwarf–a little cooler than our Sun, a white dwarf, and an accretion disk surrounding the white dwarf. The brightening by 2 to 6 magnitudes is due to instability in the disk which forces the disk material to drain down (accrete) onto the white dwarf. There are three main subclasses of dwarf novae; U Gem, Z Cam, and SU UMa stars.

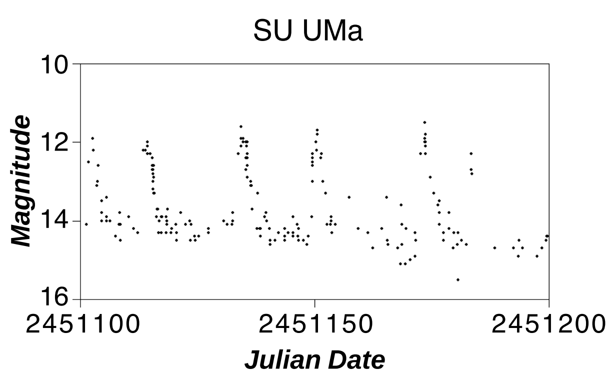
U Geminorum – After intervals of quiescence at minimum light, they suddenly brighten. Depending on the star, the eruptions occur at intervals of 30 to 500 days and last generally 5 to 20 days.



Z Camelopardalis – These stars are physically similar to U Gem stars. They show cyclic variations, interrupted by intervals of constant brightness called "standstills". These standstills last the equivalent of several cycles, with the star "stuck" at the brightness approximately one-third of the way from maximum to minimum.

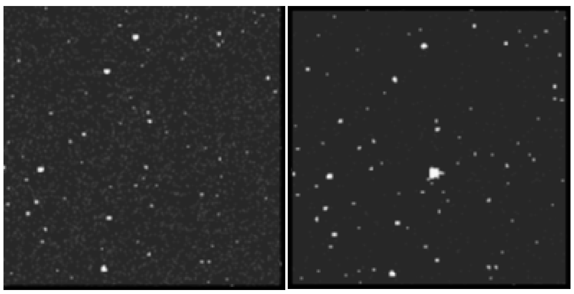


SU Ursae Majoris – Also physically similar to U Gem stars, these systems have two distinct kinds of outbursts: one is faint, frequent, and short, with a duration of 1 to 2 days; the other ("superoutburst") is bright, less frequent, and long, with a duration of 10 to 20 days. During superoutbursts, small periodic modulations ("superhumps") appear.

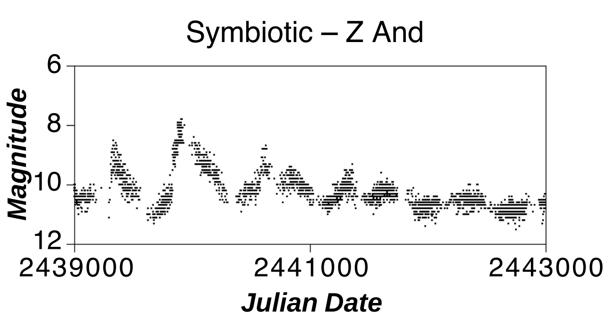


U Geminorum

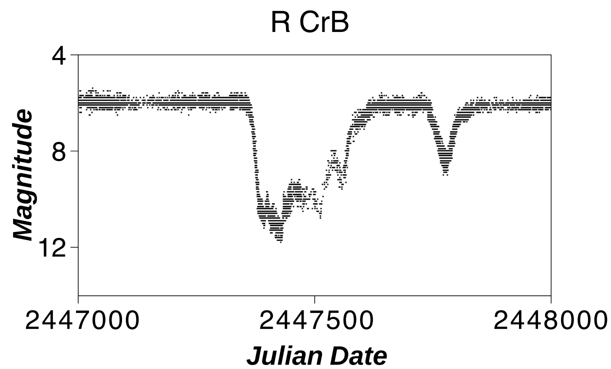
Below are 20-second exposures of U Gem before outburst and after the start of an outburst. Images were taken by AAVSO Director Arne Henden, USRA/USNO, using a CCD with a V filter on the U. S. Naval Observatory 1.0-m telescope in Flagstaff, AZ. Beneath the photos is the artist, Dana Berry's, rendition of the U Gem system (note the sun-like star to the right, the white dwarf, and the accretion disk surrounding the white dwarf).



Symbiotic stars – These close binary systems consist of a red giant and a hot blue star, both embedded in nebulosity. They show semi-periodic, nova-like outbursts, up to three magnitudes in amplitude.

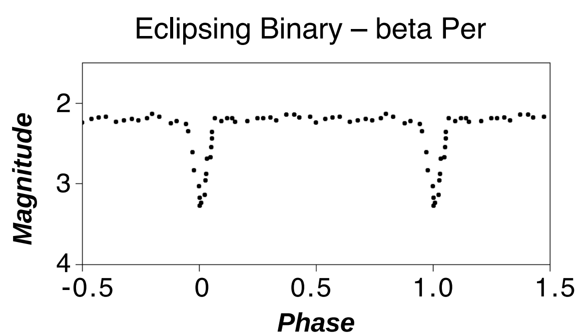


R Coronae Borealis – These rare, luminous, hydrogen-poor, carbon-rich, supergiants spend most of their time at maximum light, occasionally fading as much as nine magnitudes at irregular intervals. They then slowly recover to their maximum brightness after a few months to a year. Members of this group have F to K and R spectral types.



ECLIPSING BINARY STARS

These are binary systems of stars with an orbital plane lying near the line-of-sight of the observer. The components periodically eclipse one another, causing a decrease in the apparent brightness of the system as seen by the observer. The period of the eclipse, which coincides with the orbital period of the system, can range from minutes to years.



ROTATING STARS

Rotating stars show small changes in light that may be due to dark or bright spots, or patches on their stellar surfaces ("starspots"). Rotating stars are often binary systems.

Courage! Each step forward brings us nearer the goal, and if we can not reach it, we can at least work so that posterity shall not reproach us for being idle or say that we have not at least made an effort to smooth the way for them.

– Friedrich Argelander (1844)
the “father of variable star astronomy”